(12) UK Patent Application (19) GB (11) 2 084 254 A

(21) Application No 8031027
(22) Date of filing 25 Sep 1980
(43) Application published 7 Apr 1982
(51) INT CL[3] F01C 1/107 21/08 21/10//E21B 4/02 F01C 5/04
(52) Domestic classification F1F 1N1 2N3 EV EW
(56) Documents cited WO 80/02176A
(58) Field of search F1F

(71) Applicant
Vsesojuzny Nauchno-Issledovatelsky Institut Burovoi Tekhniki,
Leninsky prospekt, 6
Moscow, Union of Soviet Socialist Republics

(72) Inventors
Dmitry Fedorovich Baldenko,
Talgat Nazmetdinovich Bikchurin,
Jury Vyacheslavovich Vadetsky,
Moisei Timofeevich Gusman,
Anatoly Mikhailovich Kochnev,
Samuil Solomonovich Nikomarov

(74) Agents
Marks & Clerk,
57—60 Lincoln's Inn Fields, London WC2A 3LS

(54) Rotary Positive-displacement Fluid-machine

(57) In a motor of the Moineau type the stator 3 has one more helical tooth than the rotor 4 and to improve the performance the ratio of the helical pitches T, *t* of the stator and rotor teeth is directly proportional to ratio of the numbers of said teeth and moreover, the ratio of each of said helical pitches to the respective pitch diameter D_1 or D_2 lies in a range that is substantially 5.5 to 12. The working fluid may be a hydraulic one e.g. drilling mud, and the motor may be a down-hole earth-boring tool motive-power unit.

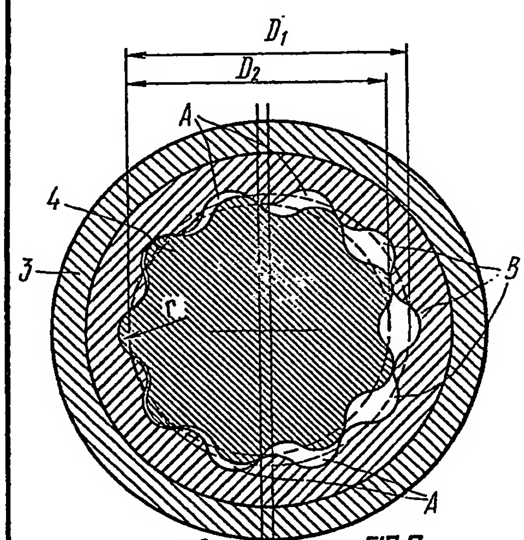

FIG.2

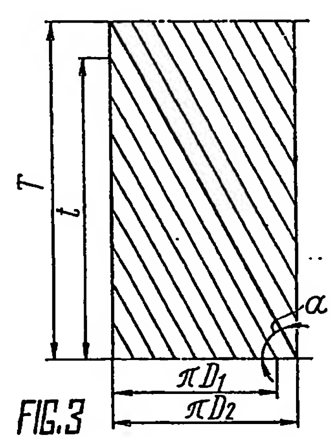

FIG.3

GB 2 084 254 A

SPECIFICATION
Bottom-hole Multistart Screw Motor

The invention relates to bottom-hole multistart screw motors.

The invention may be most advantageously applied to bottom-hole hydraulic screw motors drilling oil, gas, and prospecting boreholes.

The invention provides a multistart helical planetary gear motor comprising a stator internally provided with a helical thread and a rotor which is arranged eccentrically in the stator and is externally provided with a helical thread, the rotor and stator forming a kinematic couple which is in permanent engagement similarly to an internal gearing, the number of stator teeth being greater than the number of rotor teeth by unity, the ratio of pitches of helical threads of the stator and rotor being directly proportional to the respective ratio of the numbers of their teeth, and the ratio of pitches of the helical surfaces of the stator and rotor to their respective pitch diameters ranging substantially from 5.5 to 12.

The provision of a multistart screw motor having the above-specified geometrical parameters of working members makes it possible to eliminate self-braking phenomena under all normal operating conditions of the motor, especially during starting, thus enhancing the reliability and operating stability of the motor.

The invention will be described further, by way of example, with reference to the accompanying drawings, in which:

Figure 1 shows a general view, in longitudinal section, of a bottom-hole multistart screw motor;

Figure 2 is an enlarged section on the line II—II in Figure 1;

Figure 3 shows a developed view of working members of the motor; and

Figure 4 is a graph showing the variations of torque M developed by the motor and the liquid leakage rate q in working members as a function of a parameter C_t.

Figure 1 shows an embodiment of a hydraulic screw motor for drilling wells. In this embodiment the motor is actuated by a fluid supplied under pressure; water, drilling mud, or another liquid may be used as the fluid. The type of fluid under pressure is chosen depending on specific geological and production drilling conditions.

The screw motor comprises a casing 1 in which is rigidly secured a resilient lining 2. The lining 2 is normally made of rubber, but it may be made of any other resilient material. The lining is internally provided with a multistart helical thread. The number of starts of the helical thread corresponds to the number of teeth Z_1 of the helical surface of the lining. In this specific embodiment $Z_1=10$, although it may vary largely depending on technical requirements imposed on the motor.

The casing 1 and the lining 2 together form a stator 3 of the screw motor. The stator 3 accommodates a rotor 4 which is normally made of metal. The rotor 4 is externally provided with a helical thread in which the number of teeth $Z_2=Z_1-1=9$. The rotor 4 is installed in the stator 2 with an eccentricity e (Figure 2), and the ratio of the pitch T (Figure 3) of the helical surface of the stator 3 to a pitch t of the helical surface of the rotor 4 is directly proportional to the ratio of their numbers of teeth, that is

$$\frac{T}{t}=\frac{Z_1}{Z_2}$$

The stator 3 and the rotor 4 (Figure 2) form a kinematic couple which is in permanent engagement similarly to an internal gearing with a difference in the numbers of teeth equal to unity. The helical teeth of the rotor 4 and stator 3 engage one another to define chambers closed over the length of pitch T.

Figure 3 shows a developed view of the lateral surfaces of the stator and rotor over the length of the stator pitch T having pitch diameters D_1 and D_2, respectively. Oblique solid lines show lines of contact of the stator and rotor, and intervals between these lines represent chambers filled with a fluid.

Figure 2 shows the cross-sectional configuration of a helical planetary gear mechanism in which the cross-sectional shape of the stator 3 is formed by alternating portions of a cycloidal curve defining the teeth of the stator 3 and arcs of circles of a radius r defining teeth spaces in the cross-section of the stator. The cycloidal curve which constitutes the basis for the construction of the profile of the stator 3 is formed by rolling without sliding over an initial pre-set circle of the stator 3 another circle of a diameter which is chosen depending on the eccentricity e. The initial pre-set circle of the stator generally depends on expected operation conditions of the mechanism and is determined by maximum diametrical size which is admissible under given conditions.

The cross-sectional profile of the rotor 4 is conjugated to the profile of the stator 3 and is formed by an envelope of the initial profile of the stator 3 by rolling the pitch circle of the rotor 4 over the pitch circle of the stator 3.

The rotor 4 is connected by means of a double-hinged joint 5 to an output shaft 6 attached at the end to a drilling tool of the bottom-hole motor (not shown). The output shaft 6 is journalled in a housing 7 by means of radial bearings 8. Thrust bearings 9 provided in the housing 7 are used for taking up axial loads during operation of the bottom-hole motor.

The bottom-hole motor functions in the following manner.

A hydraulic pump feeds liquid under a given pressure along pipes to a cavity A of the motor in which the same pressure is established. The cavity A is referred to as a high-pressure cavity. The helical teeth of the rotor 4 and stator 3 engage one another to define chambers closed over the length of the pitch T of the helical surface

of the stator 3. A number of chambers thus communicate with the high-pressure cavity A, and a number of chambers communicate with a low-pressure cavity B. Therefore, an unbalanced force occurs in ever cross-section of the mechanism, and hence a torque is developed. Under the action of these forces radial deformation of the resilient lining 2 of the stator 3 takes place, and the rotor 4 is caused to move tranversely of its axis, whereafter the rotor performs a planetary motion to roll over the teeth of the stator 3 (in the clockwise direction in Figure 2).

The rotor 4 imparts rotary motion to the output shaft 6 through the double -hinged joint 5, and the motion is transmitted to the drilling tool of the bottom-hole motor.

As shown by theoretical studies and experiments, starting performance and reliability of the screw motor in operation largely depend on a parameter C_t. The parameter C_t represents the ratio of the stator and rotor pitches T and t to their respective pitch diameters D_1 and D_2.

Assuming that the working members of the motor form a screw-and-nut gearing, the relationship between the theoretical torque M of the motor and the axial force G applied to the rotor is as follows:

$$M = \frac{GD \tan(\alpha - \beta)}{2},$$

where

D is the pitch diameter of the screw- and-nut gearing,

α is the helix angle,

β is the angle of friction, i.e. arc tan f, where f is the coefficient of friction of the rotor-stator system.

Under certain conditions, in a bottom-hole screw motor, the coefficient of static friction f may take values close to or even greater than unity, and the angle of friction β in such cases approximates the angle α. Therefore, such friction conditions are possible when the value of $(\alpha - \beta) \to 0$, and self-braking occurs in the mechanism so that the motor cannot be started.

This disadvantage is eliminated in the bottom-hole screw motor according to the invention, the working members of which form a multistart helical planetary gear mechanism featuring the ratio of the pitch t of helical surface to the pitch diameter D substantially within the range C_t=5.5 to 12.

For working members featuring the parameter C_t=5.5 to 12 the helic angle is within the range α=62 to 75° so that self-braking of the mechanism is prevented. This relationship of geometrical parameters of working members is illustrated in Figure 3.

Physical sense of self-braking phenomena occurring in screw motors is illustrated in Figure 4, showing the variation of torque developed by the motor depending on the parameter C_t, and also the change in relative leakage rate. Two values—torque M developed by the motor as a percentage ratio to the torque developed at C_t=12 and leakage rate q relative to the reference leakage rate (100%) at C_t=4.6—are plotted at the ordinates in Figure 4. The abscissa is the dimensionless parameter C_t.

Curve 10 shows the relationship of torque M developed by the screw motor versus C_t at maximum coefficient of friction, and curve 11 shows the relationship of torque M developed by the motor versus C_t at minimum coefficient of friction. Curve 12 shows the leakage rate q versus the parameter C_t.

As can be seen from Figure 4, in motors characterized by C_t<5.5 at maximum coefficient of friction, f_{max} (curve 10), friction losses may be so big that the developed torque approaches zero, and self-braking conditions occur. At minimum coefficient of friction (curve 11) the self-braking conditions occur in mechanisms with $C_t \approx 2$. Therefore, to ensure reliable operation of a motor, it is sufficient that the parameter C_t should be substantially at least 5.5. This is the lower limit of the parameter C_t. The upper limit of the parameter C_t depends on the leakage rate through the working members. As can be seen from Figure 4 (curve 12), the leakage rate starts intensely growing at C_t>12.

The range of the parameter C_t according to the invention ensures stable starting and high reliability of the motor in operation.

Another advantage of the motor described above resides in that an increase in the parameter C_t, with the other geometrical parameters of the working members remaining unchanged, results in a reduction of rotary speed of the output shaft so that the footage per bit run increases.

Therefore, the invention enables a substantial improvement of reliability and starting performance of the motor, and output performance of the motor is also improved to a certain extent. Savings from the introduction of the motor according to the invention result from saving of trip time associated with failure of a motor deep in the well and also from increased tool footage.

Claims

1. A multistart helical planetary gear motor, comprising a stator provided internally with a helical thread, a rotor provided externally with a helical thread and arranged eccentrically within the stator, the rotor and stator forming a kinematic couple which is in permanent engagement, the number of teeth of the stator being one greater than the number of the teeth of the rotor, the ratio of the pitches of the helical threads of the stator and rotor being directly proportional to the ratio of their numbers of teeth, the ratio of the pitches of the helical surfaces of the stator and rotor to their respective pitch

diameters being substantially in the range from 5.5 to 12.

2. A multistart helical planetary gear motor substantially as described with reference to, and as shown in, the accompanying drawings.

Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1982. Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

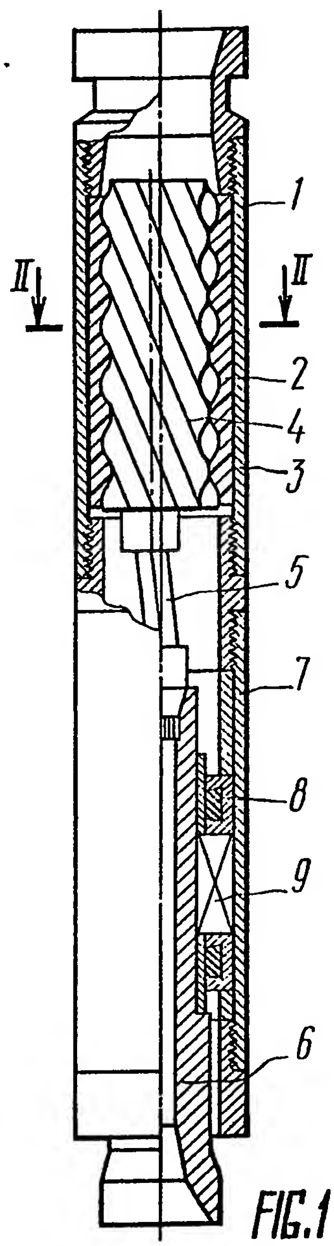

FIG.1

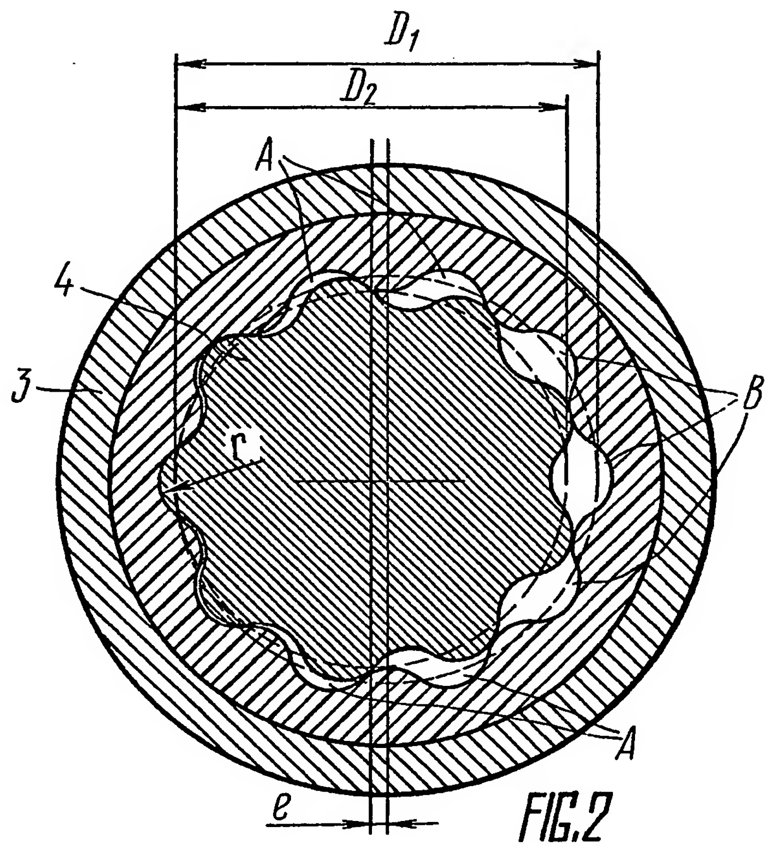

FIG.2

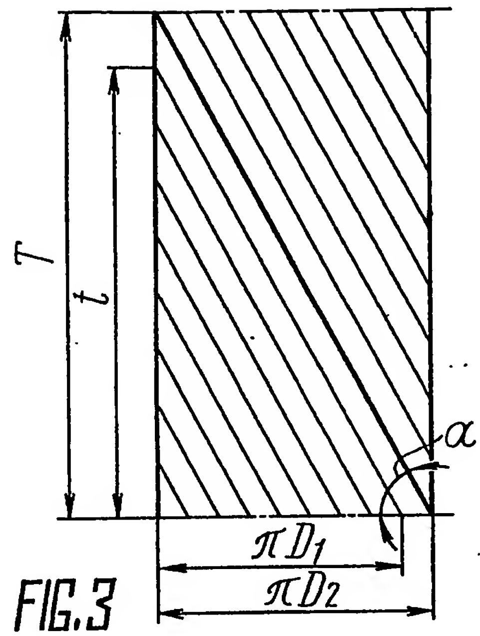

FIG.3

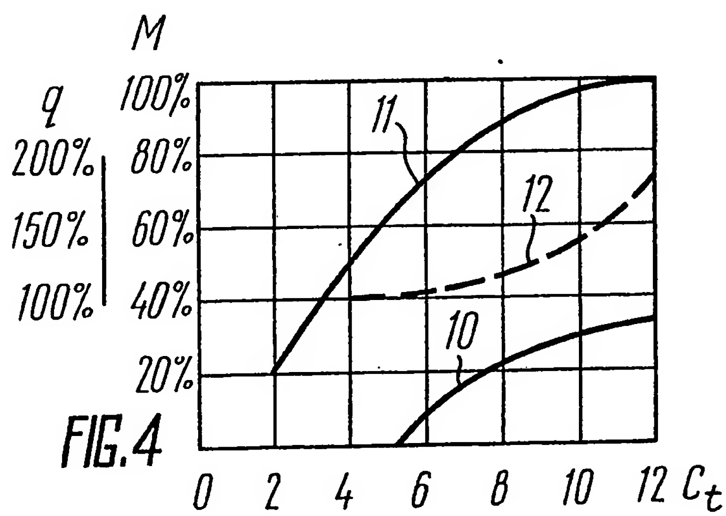

FIG.4